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MANGO: PROCESSED PRODUCTS

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Agricultural Research Service
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MANGO: PROCESSED PRODUCTS

John E. Brekke, Catherine G. Cavaletto, Allan E. Stafford,
and H. T. Chan, Jr. 1/

INTRODUCTION

The mango (Mangifera indica), indigenous to southern Asia, probably originated in the Indo-Burma area thousands of years ago (Singh, 1960). 2/ It was first introduced into Hawaii from Mexico between 1800 and 1820 by Don Francisco de Paula y Marin, a Spanish horticulturist (Yee, 1958); it later came to be known as the Hawaiian or common mango. Mango trees were also brought from the Philippines to Hawaii by Captain John Meek in 1824. Since that time, many other cultivars of mango have been introduced, and the tree now flourishes in many gardens and small plantings.

Commercial production of mangoes is probably greatest in India where 2 million acres yield approximately 5 million tons of fruit annually. Mangoes are also produced in Indonesia, Florida, Mexico, Queensland, South Africa, Egypt, Israel, Brazil, Cuba, and the Philippines (Ochse et al., 1961; Purseglove, 1968; Singh, 1960). The real economic importance of the crop in most of these areas lies in local consumption; the fruit ranks low as an export crop (Kay, 1966).

In spite of its excellence, the mango has not been developed as a commercial crop in importance in Hawaii for several reasons. The market for fresh mangoes is limited as plant quarantine regulations prohibit the export of fresh mangoes to the U.S. Mainland, Japan, Australia, and other potential markets because of the mango seed weevil. Therefore, most of the fresh fruit must be directed to local markets; some have been exported to Alaska and Canada. An abundance of backyard plantings provides a large supply of homegrown fruit and has limited the development of a local fresh market. In addition, irregular production may give rise to a crop shortage one year and surplus in the following year, resulting in great price fluctuations and undependable supply.

Another possible outlet for mangoes is the processed fruit market. Mango products, such as pickles, chutney, and canned slices, have been available for some years from Jamaica, India, Mexico, and South Africa (Kay, 1966) as well as from Puerto Rico (Sanchez-Nieva, Rodriguez, and Benero, 1959). Other speciality products have been produced experimentally and described in the literature. Brief mention is made below for those who may be interested in seeking further information on them.

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2/ The author's name followed by an underscored year refers to Literature Cited, p. 19.

Mango slices in brine are produced mainly in India and Jamaica, although in very small supply (Kay, 1966). Brined mango slices are re-manufactured into chutney for the most part. Chutney is made from fresh or brined fruit, sugar, salt, vinegar, garlic, chili peppers, ginger, and other spices. It is commonly used as a condiment with curry dishes. Formulations are varied extensively to appeal to specific preferences.

A mango cereal flake product, described by Jain, Lal, and Krishnamurthy (1957) as tasty and nutritious, has attracted much attention in India. It is the drum-dried mixture of mango pulp, cooked flour paste, and sugar, and contains 1.2 to 2.0 percent moisture. De Martin (1969) reported on mango processing investigations in Brazil where a semicommercial mango canning line is in operation; test marketing of the product has been done in Europe. Workers in Queensland have developed canned mango slices for export (Loxton, 1970). Moy (1971) reported on the vacuum-puff freeze drying of mango puree and blends of mango with other tropical fruits.

Attempts at commercial processing of mango in Hawaii have thus far been unsuccessful for a number of economic and technical reasons. Among these reasons is the high cost for hand labor involved in the preparation of mangoes for processing. No mechanical peelers or slicers have been devised for mango, although Czyhrinciw (1969) noted that abrasive peeling of frozen mangoes can be done. This procedure was tested at this laboratory but was judged to have little promise as a commercial unit operation.

Methods for processing mangoes to liquid, frozen, and dried products have been investigated in this laboratory. In this publication, new procedures for mechanizing some of the unit operations are described, and measurements of quality and stability of products are reported.

CHARACTERISTICS AND COMPOSITION OF MANGO

The ovate-oblong mango fruit varies in size among cultivars, some fruits weighing as much as 1 lb. The flat, oval seed is usually clingstone, but some cultivars that grow in Hawaii such as 'White Pirie' and 'Smith' tend to have the freestone characteristic (Yee, 1958; Yee, personal communication, 1972). The seed comprises 9 to 27 percent of the weight of the whole fruit, depending upon the cultivar (Orr and Miller, 1955). Skin or peel color varies from green to yellow and red in ripe fruit. The peel portion of the cultivars of Hawaiian mangoes appears to consist of three different types of tissue. The outermost layer is a very thin, waxy cuticle beneath which is a thin (0.1 mm), tough, highly pigmented pellicle; beneath this is a layer (1 to 2 mm) of fibrous, firm tissue. These three layers are generally referred to as the peel or exocarp. It is desirable to remove the peel in preparing cheeks and slices for freezing or canning.

Mango cultivars most plentiful in Hawaii include 'Haden', Pirie' (Yee, 1958), 'Pope' (Hamilton, 1960), and 'Edward'. A number of other cultivars, ('Buchanan', 'Joe Welch', 'Kensington', 'Irwin', 'Gouveia', 'Waterhouse', 'Zill', 'Momi K') have also been produced. The characteristics and composition of several cultivars grown in Hawaii have been reported (Orr and Miller, 1955; Wenkam and Miller, 1965). The nature of the waxes of mango was determined by Khanna and Perkins (1970) to be esters of C-18 to C-29 alcohols with hexacosanoic and tetracosanoic acid.

The mango is considered by Wenkam and Miller (1965) to be a good-to-excellent source of pro-vitamin A. Jungawala and Cama (1963) reported

12.5 mg/100 g of carotenoids in mango pulp; de George et al. (1969) reported 0.4 to 7.9 mg/100 g of β-carotene in mangoes produced in Puerto Rico. Table 1 shows the total carotenoid content of a number of mango cultivars in Hawaii during 6 crop years. Considerable variation may be seen within a given cultivar as well as among cultivars. The cultivars 'Haden' and Pirie' are considered only a fair source of ascorbic acid (15 mg/100 g) by Wenkam and Miller (1965). Data from the study reported here (table 1) would indicate that 'Haden' might be a somewhat better source than previously thought.

Percent total solids and percent soluble solids ranged from 14 to 17 percent in most cultivars but are somewhat higher for 'Zill', 'Pirie', 'Waterhouse', and 'Edward' (table 1).

Color of both skin and flesh vary with maturity and cultivar. Proctor and Creasy (1969) found a single anthocyanin, peonidin-3-galactoside, in the skin of 'Haden' mangoes. However, flesh color appears to be attributed to the presence of carotenoids (table 1). General observations on the two cultivars most frequently sampled for analysis were that 'Haden' had a darker yellow-orange flesh than 'Edward'; the latter was usually light yellow by comparison.

The pH of a food product is an important attribute to consider in heat processing. At pH values greater than 4.5, severe heat treatment is required to kill spores of Clostridium botulinum; such treatment would cause heat damage to the flavor of mango. By adjusting the pH to below 4.5, much less severe heating is required and flavor changes are minimized. Thus, it is imperative that the pH of mango products for heat processing be determined and that the product be acidified sufficiently to render the pH well below 4.5 (that is, 3.5 to 4.0). Acidified sirup must be used on slices for canning to adjust the pH of the product. Values of pH 4.5 or slightly above have been recorded for mangoes (Bruno and Goldberg, 1963; Orr and Miller, 1955). Those cultivars listed in table 1 ranged from pH 3.85 to 4.50.

Some persons show an allergic reaction to mango. The exact nature of the allergen has not been established, but it is considered by some (Kunishi and Seale, 1961) to be 3-pentadecylcatechol. This compound is found in other plants of the family Anacardiaceae, including poison ivy (Rhus).

The presence of D-manno-heptulose and D-altro-heptulose in mango was established by Ogata et al. (1972) in a study of 10 tropical fruits in Hawaii. The 7-carbon sugars were suspected to have some connection with increased incidence of measurable quantities of sugar in urine of diabetics during the harvest season of some of these fruits. El Ansari et al. (1971) isolated β-glucogallin and gallotannin from mature green mango fruit; the toxic gallotannin was present to a small or negligible extent in well-ripened fruit.

Naturally occurring enzymes can cause off-flavor development or color deterioration in food products. The edible portion of 'Haden' mango was examined in this laboratory for the presence of peroxidase, catalase, polyphenolase, pectin methyl esterase, and polygalacturonase. (See Appendix for procedures.)

Peroxidase activity was present at all stages of maturity, but most active in green and half-ripe mango fruit. Peroxidase tests on clear filtrates of mango fruit homogenates were negative; however, peroxidase was detected in the filter cake. Apparently, peroxidase is bound to the insoluble portions of the fruit tissue.

Slices of ripe mango flooded with 3 percent hydrogen peroxide gave a positive catalase reaction; no activity was apparent in green slices. With the Smith fermentation tube method, ripe mango homogenate gave a strong positive reaction with copious gas formation; a homogenate of green mango

TABLE 1.--Composition of edible part of mangoes in Hawaii [1/]

Cultivar	Year	Total solids	Soluble solids (Brix°)	pH	Total acid (as citric)	Ascorbic acid	Carotenoids
		Percent			Percent	Mg/100 g	Mg/100 g
'Haden'	1965	17.2	15.5	4.05	0.33		
	1966		15.0	4.20			
	1967	14.7	14.4	4.10	.27	25	3.7
	1967		16.5	3.95	.37	40	
	1967	16.3	15.2	3.95	.33	29	3.2
	1967		17.1	3.90	.44		
	1967		16.3	3.90	.42		
	1967	16.7	15.6	4.00	.41		
	1968		17.0	4.50			
	1969	17.0	16.4	4.40	.21	10	5.0
	1970	15.8	15.5	4.13	.36		2.9
	1970	17.3	17.1	4.30	.29	9	
	1971		14.2	4.20			
	1971		15.3	4.10			
	1971		15.9	4.25			
'Edward'	1967	20.7	20.2	4.20	.34		
	1967	22.6	19.7	4.20	.36	20	2.9
	1967		20.5	4.20	.37		
'Joe Welch'	1970	15.4	15.1	3.85	.51		4.5
	1970	14.4	14.2	4.50	.21	24	
'Pope'	1970	17.7	17.4	4.28	.32		4.5
	1970	16.7	16.2	4.10	.35		2.7
'Pirie'	1970	20.0	19.4	4.10	.36		3.6
'Zill'	1970	19.3	18.8	4.35	.29	12	
'Waterhouse'	1970	22.6	21.0	4.20	.47		3.6
'Buchanan'	1970	17.8	17.5	4.20	.31		3.7
'Irwin'	1970	15.6	14.7	4.05	.27		1.4

1/ See Appendix for analytical methods; samples in duplicate.

showed only a trace of catalase activity. To determine whether this was a pH effect, sodium acetate was added to the homogenate of green mango tissue to raise the pH from 3.7 to 4.2, which was more nearly that of ripe mango. A great increase in catalase activity was noted in the homogenate of green fruit adjusted to pH 4.2.

Polyphenolase was present in green mangoes, particularly in the exocarp; only trace amounts were detected in the ripe fruit. Only a trace amount of pectin methyl esterase activity was seen in any samples. No polygalacturonase activity was detected in any samples.

PROCESSING METHODS AND PRODUCTS

Postharvest Handling

Fresh fruit delivered to a processing plant must be handled so that its quality will not deteriorate before it is processed. Refrigeration at 55° F is recommended (Akamine, 1963) as fruits at the mature green or ripe stages of maturity can be held for a week at this temperature without quality loss. Upon removal from refrigerated storage, mature green mangoes can be ripened at 75° to 80° in 2 to 3 days. Mangoes at the eating ripe stage may be greenish yellow, yellow, or deep yellow-orange with crimson or rose blushes on the cheeks, depending upon the variety. The flesh is yellow to orange, juicy and sweet, and soft enough to be easily removed from a halved fruit with a spoon. Fruit at the eating ripe stage was used for the work reported here.

Peeling

Steam Peeling

Removing mango peel with the aid of steam has been shown to be feasible by work at this laboratory. Whole fruit was exposed to atmospheric steam in a chamber for varying lengths of time, then cooled in a water bath. A small slit was cut in the peel, and it was easily slipped off by hand. Heating for 2-1/2 min in steam was sufficient for any variety tested. Cultivar differences were seen in the ease with which steam peeling was accomplished, thinner peels being more easily removed. 'Haden' and 'Buchanan' had the thickest peels, whereas 'Pirie', 'Joe Welch', and a number of other cultivars had comparatively thin peels, which could be slip-peeled after 2-min steaming. One minute of steaming was inadequate for any cultivar tested. The heated tissue at and immediately below the peel assumed a translucent appearance that made it easy to determine visually how deep the heating had taken effect. A heat ring about 2 to 3 mm deep, could be seen on cross section of whole fruits that were slip-peeled. Catalase activity was destroyed in the heated tissue. A cross-sectioned fruit flooded with 3-percent hydrogen peroxide showed the ring of heated surface tissue very plainly; bubbles formed in the inner tissue, but no bubbles were on the 2- to 3-mm layer of outer tissue.

Lye Peeling

Four cultivars were included in the lye-peeling test--'Haden', 'Buchanan', 'Joe Welch', and 'Pirie'. The severity of the lye treatment depended on cultivar and maturity. In all cases, it was desirable to add a wetting agent

(about 0.2-percent sodium lauryl sulfate) to the lye bath and to score the surface of the fruit with a stainless steel wire brush before the lye treatment.

'Pirie', having the thinnest peel, was the easiest to lye peel. Treatments in 20-percent sodium hydroxide (NaOH) at 195° F for 3 min or 13-percent NaOH at 175° for 5 min were sufficient for removing the exocarp, leaving 20-percent NaOH at 195° for 3 to 5 min or 13-percent NaOH at 175° for 5 min. 'Buchanan' required a lye treatment in 20-percent NaOH at 195° for 6 min to remove the exocarp. 'Haden' was the most difficult to peel. Lye treatment in 20-percent NaOH at 212° for 5 min or at 195° for 6 to 7 min removed only the outer layers of the exocarp, the cuticle and pellicle. Only in cases of very ripe fruit were portions of the exocarp below the pellicle removed, giving a ragged appearance. Generally, green fruit was more difficult to peel than ripe fruit.

The peeling was completed by a rotary rod washer after lye treatment. The combination of water washing and gentle abrasive action caused by the tumbling of the fruit in the washer removed 90 percent or more of the peel.

Frozen Puree

Mango puree may require less hand labor than other types of mango products and thus, from the standpoint of cost of production, may have some promise as a commercial product. The puree can be used for remanufacture into jams, jellies, beverages, and dairy and bakery products.

A comprehensive treatment of processing and storage of frozen foods is found in "The Freezing Preservation of Foods" by Tressler, Van Arsdel, and Copley (1968). Certain prefreezing treatments are necessary for each frozen food; these may be as simple as merely washing or may consist of a series of unit operations such as peeling, blanching, and siruping. Rapid freezing is required for frozen food, with rare exceptions, and storage at 0° F or below has been shown to be necessary to preserve high quality (Van Arsdel and Guadagni, 1959). A critical factor in the quality retention of many frozen foods is the kind and extent of enzyme activity in the product. Recommended freezing storage temperature (0°) greatly decreases the activity but does not inactivate the enzymes. Consequently, enzymatically catalyzed reactions may proceed during processing, freezing, storage, thawing, and subsequent processing; these reactions can result in development of undesirable flavors in many products. An effective means of inactivating enzymes is heat. Experimental work in this laboratory has established the necessity for heat-inactivation of enzymes in mango puree that is to be frozen (Brekke, Cavaletto, and Stafford, 1968).

Heat Treatment Studies

'Haden' mangoes were sorted and washed in a rotary spray washer, after which the seeds were removed with knives. A mechanical scraping device (Angara, Wang, and Agena, 1969) separated the peel from the flesh or pulp. The flesh was put through a paddle pulper fitted with a screen with 0.033-inch perforations to remove coarse fibers and particles. Half of the puree was frozen immediately; the other half was pumped through a plate heat exchanger for rapid heating and cooling to inactivate enzymes and then frozen. In the heat exchanger, the temperature of the puree was raised to 195° to 200° F, held at that temperature for 2 min, then rapidly cooled to 90° to 100°. This heat treatment was sufficient to inactivate catalase. Inactivation of catalase

was used as a guide to determine the required heat treatment. The puree was poured into 30-lb tins with polyethylene liners, frozen at -10°, and then stored at 0°. It was subsequently used in preparation of nectar, and quality evaluations were made on the nectar.

To prepare nectar, puree was thawed overnight at room temperature and transferred to a large stainless steel container in which ingredients were mixed with a power stirrer. The nectar formula was as follows:

100 lb mango puree
30 lb sugar
170 lb water
10 oz citric acid (50-percent solution by weight)

After being thoroughly mixed, the nectar was poured into No. 2 cans (575 g/can) and vacuum sealed. The cans were processed 3 min in steam at 212°F in a spin cooker (Wang and Ross, 1965) in which the cans were rotated at 125 revolutions per minute on their long axis; they were spin cooled 4 min in water sprays at about 75°, sufficient to reduce product temperature to about 100°. The cans were held 3 days at room temperature (75° to 85°) before evaluation.

The nectars were evaluated by a taste panel to determine the effect of heat inactivation of enzymes on the stability of frozen puree. A nine-member panel evaluated the nectars for aroma and flavor quality on each of 5 days. The nectars were scored on a seven-point scale where 1 signified lowest quality and 7, highest quality. The samples were served at 55° F under red illumination in individual taste booths. Average scores are shown in table 2.

Nectars from heated purees were significantly higher in quality than those from unheated purees at all storage times. To determine whether the heating itself gave rise to differences in flavor, several hundred pounds of 'Haden' mangoes were pureed as above; half the puree was heated to inactivate enzymes, and half was not. A portion of each part was made at once into nectar and spin processed; the remaining portion was frozen as before. After 1 week, these frozen purees were thawed, made into nectar, and spin processed. The panel then evaluated the nectars made from freshly prepared purees and from purees that had been frozen and stored at 0° F for 1 week. The results of five tasting sessions are given in table 3.

No difference was observed in flavor and aroma quality of nectars made from heated and unheated purees that had not been frozen. However, after only 1 week of freezing storage of purees in 30-lb tins, nectars prepared from unheated purees scored significantly lower in flavor and aroma quality than nectars from heated purees. It was concluded that the rapid heating and cooling, in itself, was not responsible for the changes in aroma and flavor. The heating presumably inactivated enzymes which otherwise could be responsible for changes in flavor and aroma during the freezing, storage, and thawing.

Peeled Versus Unpeeled Fruit for Puree

Separation of flesh from seed and peel of mango requires a great deal of hand labor as it has been done in the past. Studies at this laboratory on steam peeling and lye peeling have been described in a previous section. A device for extracting a dilute mango puree and separating the seeds has been reported (Sanchez-Nieva et al., 1959); a considerable quantity of water is required, resulting in dilution of mango solids. However, Sanchez-Nieva et al.

(1959) and Siddappa and Bhatia (1955) indicated that complete separation of peel may not be necessary. At this laboratory, purees from peeled and unpeeled Haden mangoes were compared to determine whether peel separation improves the quality of the puree and canned nectar made from it.

For "unpeeled" puree, mango cheeks (halves) were cut from the eating ripe fruit and passed through a cutting mill and paddle pulper. The paddle pulper removed virtually all the pieces of peel from the milled, unpeeled halves; those bits of peel that would pass through a 0.033-inch screen remained in the puree. For the "peeled" puree, the cheeks were cut from whole mangoes and put through the rotary scraper to remove peels; then the flesh was passed through the pulper.

Purees from the peeled and unpeeled fruits were prepared for freezing by heat inactivation of enzymes as described above; after storage at 0° F for 2-1/2 and 8 months, they were thawed, made into nectars, and spin processed in No. 2 cans. Aroma, flavor, and color were evaluated after the canned nectars were held 1 week at room temperature. Aroma and flavor were evaluated as described previously. Samples for color evaluation were compared with a standard (nectar from peeled puree) and scored as lighter than (-1 to -3), same as (0), or darker than (+1 to +3) the standard. The results of five panel sessions are in table 4.

TABLE 2.--Comparison of nectars prepared from heated and unheated puree stored at 0° F

Puree storage time	Puree	
	Unheated	Heated
	Average flavor score 1/	
1 week	4.7	5.7**
1 month	4.9	5.7**
4 months	4.4	5.8**
8 months	4.1	6.0**
12 months	4.0	6.4**
	Average aroma score	
1 week	4.2	5.0*
1 month	4.7	5.3*
4 months	4.4	5.7**
8 months	4.3	6.0**
12 months	3.8	6.0**

**Significantly higher quality ($p = 0.01$).

*Significantly higher quality ($p = 0.05$).

1/ Nectars were scored on a 7-point scale where 1 signifies lowest quality and 7, highest quality.

TABLE 3.--Comparison of nectars from heated and unheated purees before and after being frozen

Puree storage time at 0° F	Puree	
	Unheated	Heated
	Average flavor score 1/	
0 2/	5.6	5.7N.S. 3/
1 week	4.1	5.5**
	Average aroma score	
0	5.5	5.7N.S.
1 week	4.4	5.8**

**Significantly higher quality (p = 0.01).

1/ Nectars were scored on a 7-point scale where 1 signifies lowest quality and 7, highest quality.

2/ Nectar made from freshly prepared puree; no freezing.

3/ N.S. = Not significantly different.

TABLE 4.--Comparison of mango nectars from "peeled" and "unpeeled" puree--average aroma, flavor, and color scores 1/

Puree storage time at 0° F (months)	Aroma		Flavor		Color	
	Peeled	Unpeeled	Peeled	Unpeeled	Peeled	Unpeeled
2.5	5.3	6.1**	5.3	6.2**	0	+0.5**
8	5.8	2/ 6.1	5.3	6.2**	+ .3	+ .9**

**Significantly different (p = 0.01).

1/ Nectars were scored on a 7-point scale where 1 signifies lowest quality and 7, highest quality.

2/ N.S. = Not significantly different.

The inclusion of peel before pulping improved the flavor of nectars made from these purees. Nectars from unpeeled puree were slightly darker than those from peeled puree. These data show that the removal of peel before pulping is not necessary for the production of high-quality mango puree.

Thus, a simplified technique for processing mangoes into puree was devised and operated successfully in repeated tests. Whole, eating-ripe mangoes of mixed cultivars were washed, exposed to atmospheric steam for 2 to 2-1/2 min in a loosely covered chamber, then transferred to a stainless steel tank. Steam treatment softened the skins sufficiently that the fruits could be broken up and pulped by a power stirrer fitted with a saw-toothed propeller blade and mounted 5 to 6 inches below a regular propeller blade (fig. 1). A 1/4-hp, 220-V, three-phase power stirrer was used for 200-lb batches. The propellers rotated at 350 r/min and broke up the fruit to a mixture of pulp, pieces of skin, and seeds. The pulp was removed from the seeds without the seeds being cut or broken. Large pieces of peel and the seeds were separated from the pulp by a continuous centrifuge designed for use in passion fruit juice extraction (Kinch, 1959).

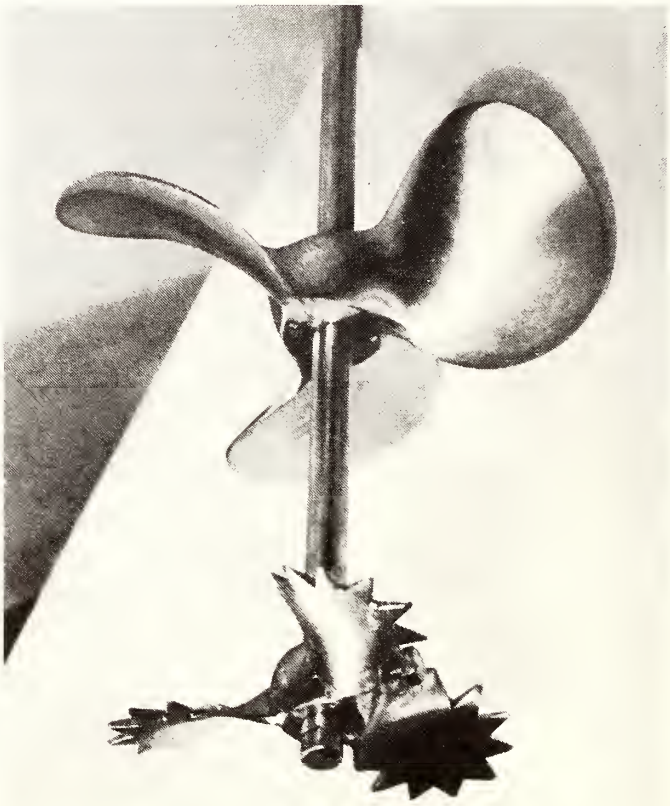

Figure 1.--Propeller blades on power stirrer.

The pulpy material was passed through a paddle pulper fitted with a 0.033-inch screen to remove fiber and small pieces of peel. The puree was then pumped through a plate heat exchanger to heat inactivate enzymes, and then cool the product. The finished puree, about 70 percent of the weight of the whole fruit, was packaged in polyethylene bags in paperboard containers (30 lb each) for quick freezing. Color and flavor of the puree after several months' storage was considered very good by informal comparisons with other samples of high-quality puree. A flowsheet for this process is given in the Appendix.

Frozen Slices

In earlier work at the Hawaii Agricultural Experiment Station (Orr and Miller, 1955), several cultivars of mangoes grown in Hawaii were frozen in packs of various types. The quality of the thawed samples was compared after several months of frozen storage. They concluded that cheeks and slices frozen in sirup were superior in quality to those packed in dry sugar, or with no added sirup or sugar. Addition of ascorbic acid did not enhance the quality.

More recent work on frozen mangoes in this laboratory included freezing four to five whole fruit packaged in a polyethylene bag (several bags of each cultivar), cheeks and slices packed in 1-pint plastic jars with screw-on lids, and cheeks and slices covered with 35° Brix sucrose sirup packed in the same type of container. After being frozen at -10° F and stored at 0° for several weeks, the samples were examined and compared informally to assess gross differences in quality. Five cultivars ('Haden', 'Waterhouse', 'Kensington', 'Buchanan', and 'Irwin') were included in the trial packs. In general, flavor of the fruit after thawing was typically that of mango. Undesirable flavors did not develop in the frozen slices and cheeks as they did in frozen puree. A possible explanation of this seeming anomaly is that tissue disruption in the slices was minimal, thus providing virtually no admixture of enzymes and substrates for undesirable reactions. The texture of the thawed samples ranged from soft to mushy. Comparison of the three freezing and packaging methods showed that the flavor of the sirup packs was slightly better than that of the dry packs primarily because sugar enhanced the mango flavor in the sirup packs. Little texture difference was seen between sirup and dry packs. Freezing whole, unpeeled fruit was the least desirable method as all samples were very soft after thawing. Cultivar differences were also evident. 'Buchanan', 'Kensington', and 'Waterhouse' had especially poor texture after thawing. Both 'Haden' and 'Irwin' stayed fairly firm when frozen as slices and were somewhat softer when frozen whole.

Steam blanching (1, 2.5, and 4 min) as a prefreezing treatment for mango cheeks was investigated. Formal evaluations by a taste panel were conducted to determine the effects of blanching on flavor quality and stability during 12-month frozen storage. Steam blanching for 4 min caused excessive softening and tissue breakdown and imparted a cooked flavor. Although the shorter blanch times did not impart a cooked flavor, results indicated that flavor quality and stability of the frozen slices were not enhanced by steam blanching.

The most satisfactory of the procedures tested for freezing mangoes was to wash, peel by hand, remove seed, cut to desired size, fill container, cover pieces with sirup (25 to 30° Brix), seal, freeze in a blast freezer at -10° F, and store at 0° or lower (see Appendix).

Canned Nectar

A nectar consists of fruit juice or puree mixed with water, sugars, and other edible additives such as acidulants and food coloring materials. Work in this laboratory has been with nectars containing 25 to 33 percent mango puree. De Leon and de Lima (1966) prepared mango nectars containing 25 percent fruit pulp, which they considered optimum fruit content. Sanchez-Nieva et al. (1959) described a method for preparing a mango pulp dispersion containing more than 50 percent by weight of added water. They prepared a nectar from the dispersion, evaluated quality, and concluded that the canned product retained its quality satisfactorily for 1 year at room temperature. Canned mango "juice" containing acidified 50 percent mango puree was processed by four different methods by Muhammed, Asghar, and Tremazi (1965). Of their processing methods, the one employing the least heat gave the best quality: Pasteurize at 190° F for 1 min, fill, seal, hold 3 min, and cool. Mahadevaiah et al. (1969) concluded that plain tin cans were preferred over lacquered cans as containers for canned nectar.

A canned nectar can be made from freshly prepared, pasteurized, or frozen puree. A typical nectar is one with 25 percent mango puree, 15° Brix, and pH 3.5. As the soluble solids of mango purees vary considerably (table 1), the formulation of the nectar must be adjusted correspondingly. Following are typical formulas for nectars made from purees containing different amounts of soluble solids (degrees Brix). Adjusting acidity to approximately pH 3.5 is done most conveniently by adding citric acid as 50 percent solution (w/w), as follows:

Nectar components	Brix of puree		
	15°	17°	20°
Puree	100	100	100
Sugar	45	43	40
Water	255	257	260

In nectar preparation, the ingredients are first thoroughly mixed with a power stirrer. Heat processing can be done by (a) spin processing; (b) flash pasteurizing to 230° F, filling at 190°, and processing the sealed cans in a boiling water bath; or (c) heating to 190°, filling, sealing, and processing in a boiling water bath. Processing in a boiling water bath sterilizes the inner surfaces of the can and lids and prevents contamination of the nectar from those surfaces. This usually requires 10 min for a can containing 20 oz of nectar.

The inclusion of peels in preparation of puree was not detrimental to the flavor of spin-cooked nectars made from frozen puree (table 4). However, it was desirable to know whether this puree preparation method could affect the color stability of heat-processed nectars. An equally important question was how color stability might be affected by the can lining.

Purees from peeled and from unpeeled mangoes were made and nectars prepared as previously described. Nectars were spin cooked in both tin-and "N" 3/ enamel-lined cans and placed in storage at room temperature (75°±3° F).

3/ "N" enamel is a type of can lining commonly used for fruit products.

A panel of eight judges ranked the color of the samples according to lightness under a Haluk grading light unit after 1 week, and after 3, 6, and 12 months storage. After each storage period, color measurements were made with a Gardner Color and Color Difference Meter.

After 1 week, the panel detected no lightness difference between nectars made from peeled and unpeeled fruit in either tin- or enamel-lined cans. After 3, 6, and 12 months storage, nectars in tin-lined cans were judged lighter in color than those in enamel-lined cans. Unpeeled samples were ranked lighter than peeled samples in tin-lined cans only. No consistent difference was observed between peeled and unpeeled samples in enamel-lined cans.

Gardner Meter $\pm a$ and $\pm b$ values, which measure the red and yellow color components, respectively, indicated only small differences throughout the storage period. Initially, the unpeeled samples were slightly more red and yellow than the peeled samples.

It was concluded that although some color differences occurred between various treatments, none of the nectars was so affected that its color was considered objectionable. Either enamel or plain tin lining is satisfactory for color stability of canned mango nectar. The effect of the can lining type on flavor stability was not determined in this laboratory. The use of either lacquer or plain tin-lined cans for mango nectar has been reported by other workers (Mahadevaiah et al., 1969; Muhammed et al., 1965; Sanchez-Nieva, 1959). The fruit need not be peeled in preparation for nectar production to assure color stability.

Drum-Dried Puree

Dried fruit products are available in the form of pieces, powders, and flakes. Techniques such as sun drying, tunnel dehydration, drum drying, spray drying, vacuum drying, vacuum-puff drying, foam-mat drying, and freeze drying have been established as commercial processes for some time. Packaged and stored properly, dried fruit products are a stable, highly acceptable, nutritious part of the diet in this country. The economic advantages in packaging, transportation, and storage by reduction of bulk and weight are obvious; these considerations are especially important in marketing products of Hawaii.

Drum drying of a fruit juice concentrate or a puree produces fruit flakes that can be further milled and screened to give a powder of desired particle size. Bose and Dutt (1952) dried mango pulp mixed with an equal volume of water on a Buflovak double drum dryer. The flake product, containing 3.5 percent moisture, was very hygroscopic but was reported to have good color, flavor, and rehydration characteristics.

Dried mango flakes and powder have been prepared at this laboratory with a steam-heated, scraped-surface, atmospheric, double drum dryer. The pilot scale dryer has drums 7-1/2 inches long and 6 inches in diameter, heated internally by steam under pressure. Material to be dried is fed into the trough formed by the two counter-rotating drums. Spacing between the drums can be adjusted to maintain the desired thickness of material deposited on the surfaces of the drums. As the drums rotate, water is

evaporated from the thin layer of material on the surface; a scraping blade is positioned to remove the dried material from the drum surface.

The important processing variables are drum speed, steam pressure, drum temperature, initial moisture content, and space between drums. These factors will govern the rate of product output, bulk density, and moisture content of the dried matieral. Drum dryers designed to operate in vacuum or at atmospheric pressure are available.

Mango purees made from several varieties have been drum dried to give dry, free-flowing products. A drum spacing of 0.010 inch, a product residence time of about 25 sec on the drum surface, and steam pressure of 45 lb/in^2 (gage) were satisfactory operating conditions for the pilot scale dryer. The dried puree was removed from the drum surface as a thin sheet which was bright yellow, and had a flavor like that of cooked mango. As with many dry powdered fruit products, mango must be dried to 3 percent moisture content or below to be easily handled in powder or flake form.

Typical operating conditions and moisture data are as follows:

Drum speed	Drying time	Steam pressure	Drum spacing	Moisture	
				Puree feed	Dried product
R/min	Sec	Psig	Inch	Percent	Percent
2.0	20	45	0.010	85	3.1
1.8	22	35	.010	83	2.7
1.5	27	45	.010	85	2.1

The products at 2.1 percent and 2.7 percent moisture were dry and easily flaked or powdered; the product at 3.1 percent moisture was too tacky to handle satisfactorily. The hygroscopic nature of drum-dried mango is shown in the following tabulation by the rate of gain in moisture content of vacuum-dried mango powders (0.01 percent H_2O) exposed to air at 80° F and 54 percent average relative humidity.

Hours	Percent moisture
0	0.01
.5	.76
1	1.50
2	2.46
4	3.75
24	7.80

These data emphasize the importance of packaging in a low humidity room and using hermetically sealed containers or otherwise protecting the product from moisture. In-package desiccation (Hendel, Burr, and Forrester, 1955; Copley, Kaufman, and Rasmussen, 1956) provides additional protection against moisture for such a product and should be considered by the processor as a means for enhancing its stability.

The stability of drum-dried mango flakes was investigated by keeping samples at different temperatures for periods up to 6 months. The puree

was drum dried in the manner described above to give a product containing 2.7 percent moisture. The flaky product was screened through a 9-mesh screen, then packed in 6-oz cans and 2-oz glass jars in a room held at 0° F to minimize absorption of moisture from the air. The containers were then vacuum sealed and placed in storage at 0°, 75°, and 100°.

Quality evaluations were made at intervals of 1, 2, 4, and 6 months. The flakes were reconstituted to puree by mixing with the required amount of water. Carotenoid content and alcohol-soluble pigments were determined. Observations on caking were also made. For sensory evaluation, the purees were made into nectars and evaluated by formal taste panels.

Alcohol-soluble pigments absorbing light at 400 nanometers showed virtually no change in the flakes held at 0° F, a relatively small increase at 75°, and a comparatively large increase at 100° (fig. 2). This large increase indicated an accumulation of brown pigments in the product and was in agreement with subjective evaluation of color of the flakes. However, the rate of change observed by the panel was somewhat different. The small increase at 75° was not sufficient to be observed by the panel.

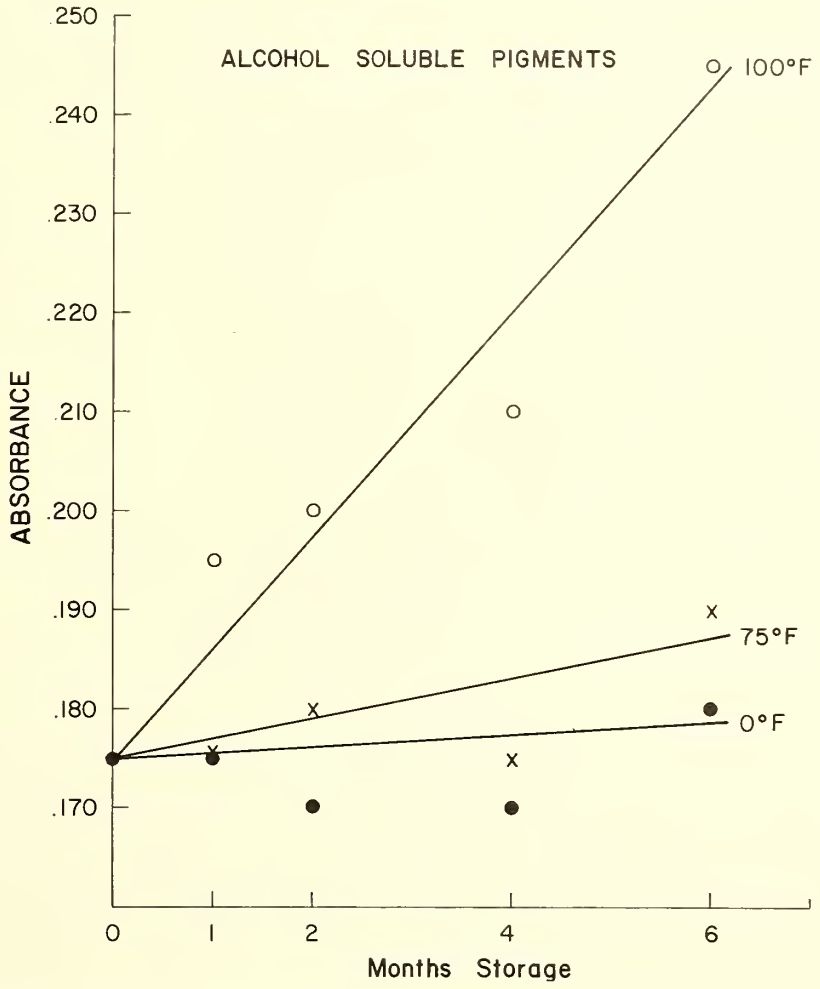

Figure 2.--The effect of temperature and time on the alcohol-soluble pigments of drum-dried mango flakes.

Changes in the carotenoid pigments were indicated by changes in the absorption spectra of petroleum ether extracts of samples withdrawn during storage. Absorbance is relative to the amount of pigment extracted in the sample preparation. We have described sample preparations in detail so that the relative values could be checked by other workers. We did not separate individual pigments for measurement. The absorbance of the mixture of pigments in an extract was used to give the comparisons between treatments and to compare with sensory observations. Figure 3 shows typical spectra of the original puree, the freshly prepared flakes, and the flakes held 6 months at 100° F.

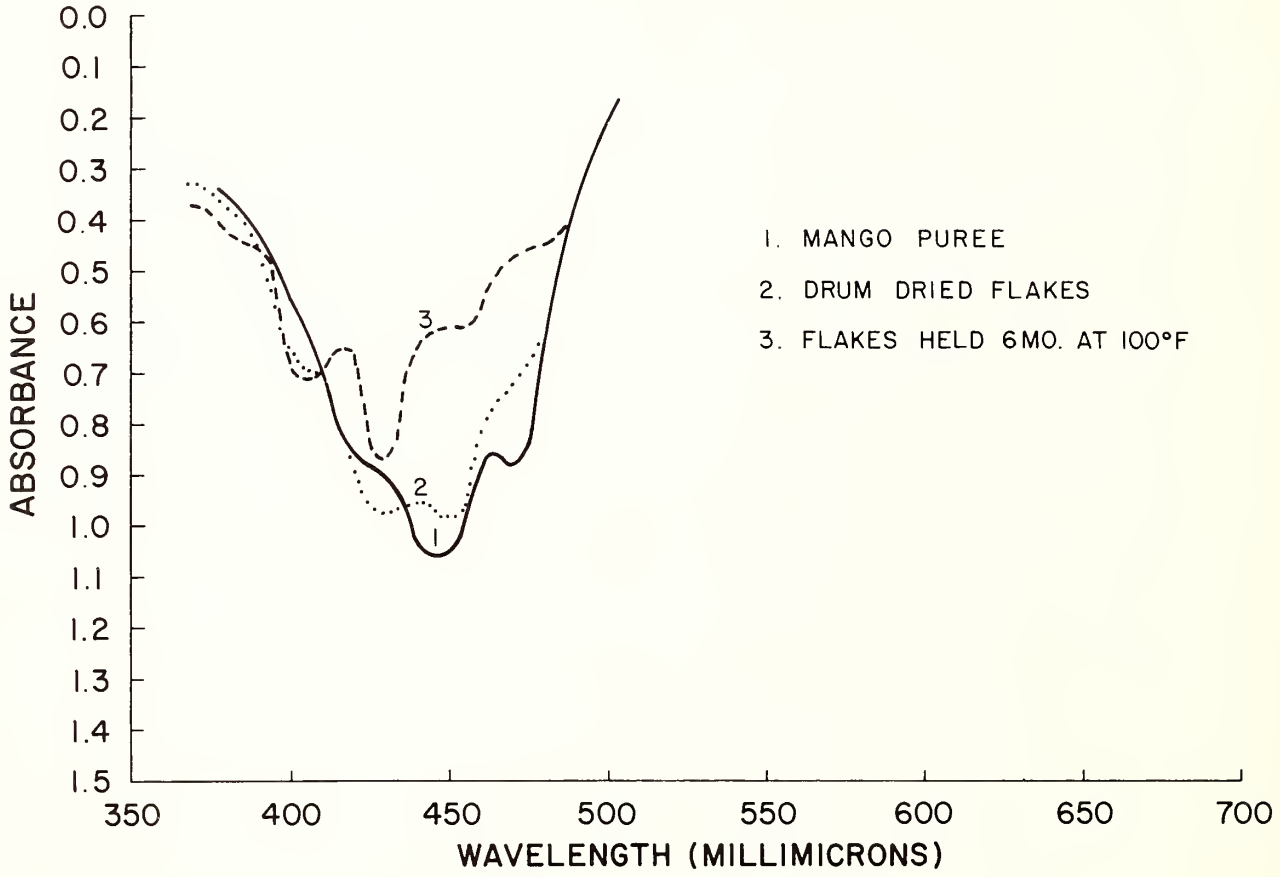

Figure 3.--Absorption spectra of carotenoid extracts of mango puree and drum-dried flakes.

The changes may be due to isomerization of 5-6 epoxy carotenoids to the 5-8 furanoid form (Curl and Bailey, 1956; Yamamoto, personal commun., 1971). In the presence of acid, epoxy carotenoid is readily converted to the furanoid form. This was demonstrated with the petroleum ether extract (carotenoids) of fresh mango puree. The extract was evaporated to dryness in a stream of nitrogen, the dried pigment was taken up in diethyl ether, and the absorption spectrum determined (fig. 4, curve 1). A few drops of 6 N HCl were added to the sample in the cuvette, the sample was thoroughly

mixed, and the absorption spectra were determined at intervals of several minutes. Curve 2 in figure 4 is the spectrum of the acidified carotenoid extract after 5 min; curve 3 is the spectrum after 30 min. This 20-nm shift in the spectrum to shorter wavelengths is typical of acid-catalyzed isomerization of mono-epoxides. These spectral changes closely resemble those seen in the extracts of freshly prepared drum-dried mango flakes and in flakes that have been held in storage at 100° F for 6 months (fig. 3).

These data strongly suggest that isomerization of carotenoids occurred during drum drying and proceeded during storage of the flakes at elevated temperatures. Naturally occuring fruit acids in the flakes presumably provided an acid medium favorable to carotenoid isomerization. The flakes stored at 0° F showed virtually no change in the spectra of carotenoid extracts; the spectra from flakes held at 75° indicated that isomerization was taking place at a rate considerably slower than at 100°. The change in appearance of the flakes during storage correlates with the accumulation of brown pigments and the loss and isomerization of carotenoid pigments.

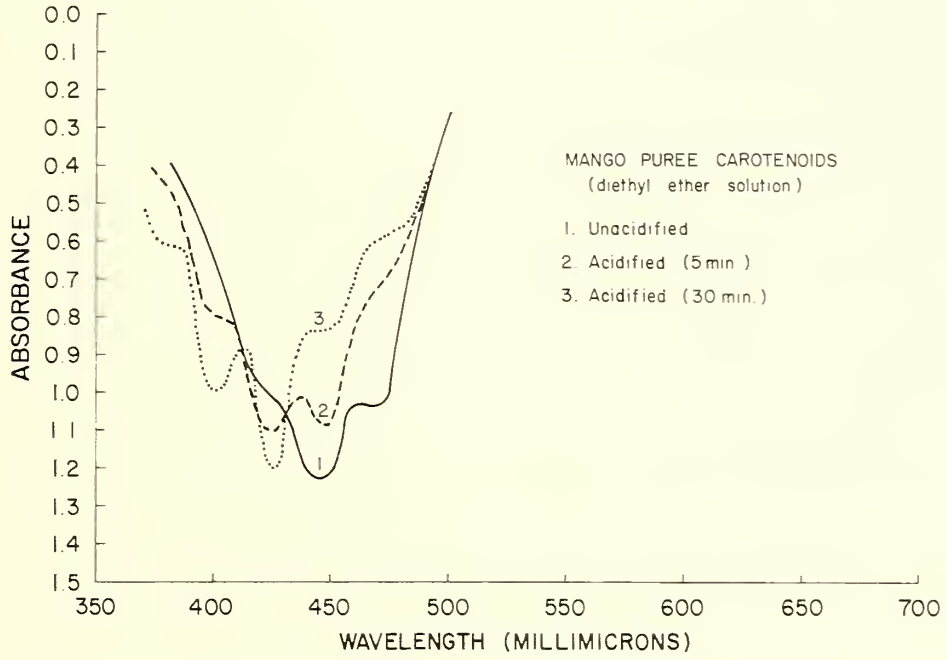

Figure 4. -- Absorption spectra of carotenoid extracts of mango puree (unacidified and acidified).

Flakes stored at 100° F began caking during the first month. At 75°, the flakes remained free flowing during the 6-month period.

After each storage interval, a panel of 10 judges rated the flavor and aroma quality of nectars prepared from the dried puree. Average flavor and aroma scores are given in tables 5 and 6. These data indicate that the flavor and aroma of the puree were stable for 6 months at 75° F. However, when the flakes were stored at 100°, deterioration of both flavor and aroma began within 1 month. Off-flavor was more evident than off-aroma.

In addition, the panel ranked the samples of dried flakes according to color to determine whether any darkening had occurred. After each storage interval, one sample of flakes from 75° and 100° F storage was placed at 0° until the 6-month period had elapsed. At that time, the samples were all removed from 0° and evaluated for color changes. In the flakes stored at 75°, no significant color changes were observed. However, in the flakes stored at 100°, the panel observed significant darkening during the first month and very little change after that. Rate of color change appeared to correspond with rates of flavor and aroma changes.

TABLE 5.--Flavor quality of nectars prepared from drum-dried mango puree

Storage time (months)	Flavor quality of nectars 1/ based on the following storage temperatures			Statistical significance
	0° F	75° F	100° F	
1	4.1	4.5	3.3	**
2	4.1	3.8	3.2	**
4	4.4	4.2	2.6	**
6	4.6	4.3	2.5	**

**Statistically significant at 0.01 probability level. Underscored numbers are not significantly different from each other.

1/ Based on 7-point quality scale, where 7=highest quality, 4=fair, 1=unacceptable.

TABLE 6.--Aroma quality of nectars prepared from drum-dried mango puree

Storage time (months)	Aroma quality of nectars 1/ based on the following storage temperatures			Statistical significance
	0° F	75° F	100° F	
1	4.1	4.1	3.5	**
2	4.2	3.9	3.8	*
4	4.1	3.9	3.1	**
6	4.4	4.4	3.7	**

*Statistically significant at 0.05 probability level. Underscored numbers are not significantly different.

**Statistically significant at 0.01 probability level. Underscored numbers are not significantly different from each other.

1/ Based on 7-point quality scale, where 7 = highest quality, 4=fair, 1=unacceptable.

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APPENDIX

Analytical Methods

Total Solids

Samples (5 to 10 g) are weighed into aluminum moisture dishes containing sand and a small stirring rod. The sample is stirred into the sand, 5 ml of 95-percent ethanol is added, and it is brought to near dryness on a steam bath. Vacuum drying is carried out at 65° C and 1 mm Hg pressure for 30 hr. Dry weight is used to calculate total solids.

Soluble Solids

A drop or two of the sample is placed on the prism of a refractometer. The refractive index is determined, and, from the appropriate reference tables, the percentage of sugar in the sample can be determined. This is expressed as percent soluble solids or degrees Brix.

Total Acid

Ten grams of sample are weighed into a 250-ml beaker, and 50 ml distilled water is added. An automatic titrimeter is used to titrate the sample to pH 8.2 with 0.1 N NaOH. The volume of base required is used to calculate the total acid present; this is expressed as citric acid.

Gardner Meter Color Reflectance Value

The Gardner Meter is standardized with a Gardner Laboratory Standard Plate C-SY-521-56. A clear glass sample holder, such as a petri dish or a Pyrex beaker containing mango puree 1 inch deep, is positioned on the meter and the Rd, a, b values are determined.

Total Carotenoids

Twenty-five grams of mango puree are extracted successively with 70-percent methanol, acetone-methanol, and acetone-petroleum ether solvents. The carotenoid pigments, after saponification, are washed into the petroleum ether layer and measured colorimetrically at 446 mm. The carotenoid content can be calculated as β-carotene by using the value

$$E\,\frac{1\ \text{percent}}{1\ \text{cm}} = 2500$$

Ascorbic Acid Assay 4/

Mango puree is extracted with 3-percent metaphosphoric acid. The extract is mixed with a standardized solution of 2,6-dichlorobenzenoneindophenol. Colorimetric measurement of this mixture at 520 nm is used to determine the amount of ascorbic acid present.

4/ Modified method of Loeffler and Ponting (1942).

Peroxidase

A freshly cut slice of mango fruit is flooded with equal amounts of 1-percent guaiacol solution (in 95-percent ethanol) and 0.5-percent hydrogen peroxide. In the presence of peroxidase, a reddish-brown color develops within 4 min.

Catalase (Two Methods)

1. A freshly cut slice of mango fruit is flooded with a 3-percent solution of hydrogen peroxide. In the presence of catalase, a foam of bubbles appears on the surface.
2. Homogenized mango tissue (10 ml) is transferred to a Smith fermentation tube. A 3-percent solution of hydrogen peroxide (5 ml) is added to the sample in the tube and mixed with it. Evolution of bubbles indicates the presence of catalase.

Polyphenolase

A freshly cut slice of fruit is flooded with a 0.5 M solution of catechol. In the presence of polyphenolase, dark-brown pigment will develop on the surface. If no color has developed after 1 hr, the test is considered negative.

Pectin Methyl Esterase

Four pounds of mango pulp are blended with 1 liter of 0.1 M NaCl. A clear juice is separated by pressing. An aliquot portion of the pressed juice is mixed with 50 ml of 0.5-percent citrus pectin NF 5/ and adjusted to pH 7.5 with 0.02 N NaOH. The reaction is followed by titration with 0.02 N NaOH at 3-min intervals for 18 min. A sample of juice heat-inactivated by being held for 3 min at 90° C is used to correct for alkali consumption due to nonenzymatic de-esterification.

Polygalacturonase (Two Methods)

Viscometric (Watters et al., 1963) method. -- Ten ml of enzyme extract (prepared as above) are mixed with 10 ml of 0.5 percent pectin solution. A portion of this is transferred to an Ostwald viscosimeter, and the drain time in the viscosimeter is observed at intervals during 30 min. In the presence of this enzyme, the drain times will decrease.

Cup-plate (Dingle, Reed, and Solomon, 1933) method. -- Two or three drops of mango pulp are placed in cups cut in an agar media containing pectin. The agar plates are held 24 hr at 35° C, then flooded with 6 N HCl. Presence of polygalacturonase is indicated by a clear zone that develops in the media around the cup in which the sample was placed.

Alcohol Soluble Pigment

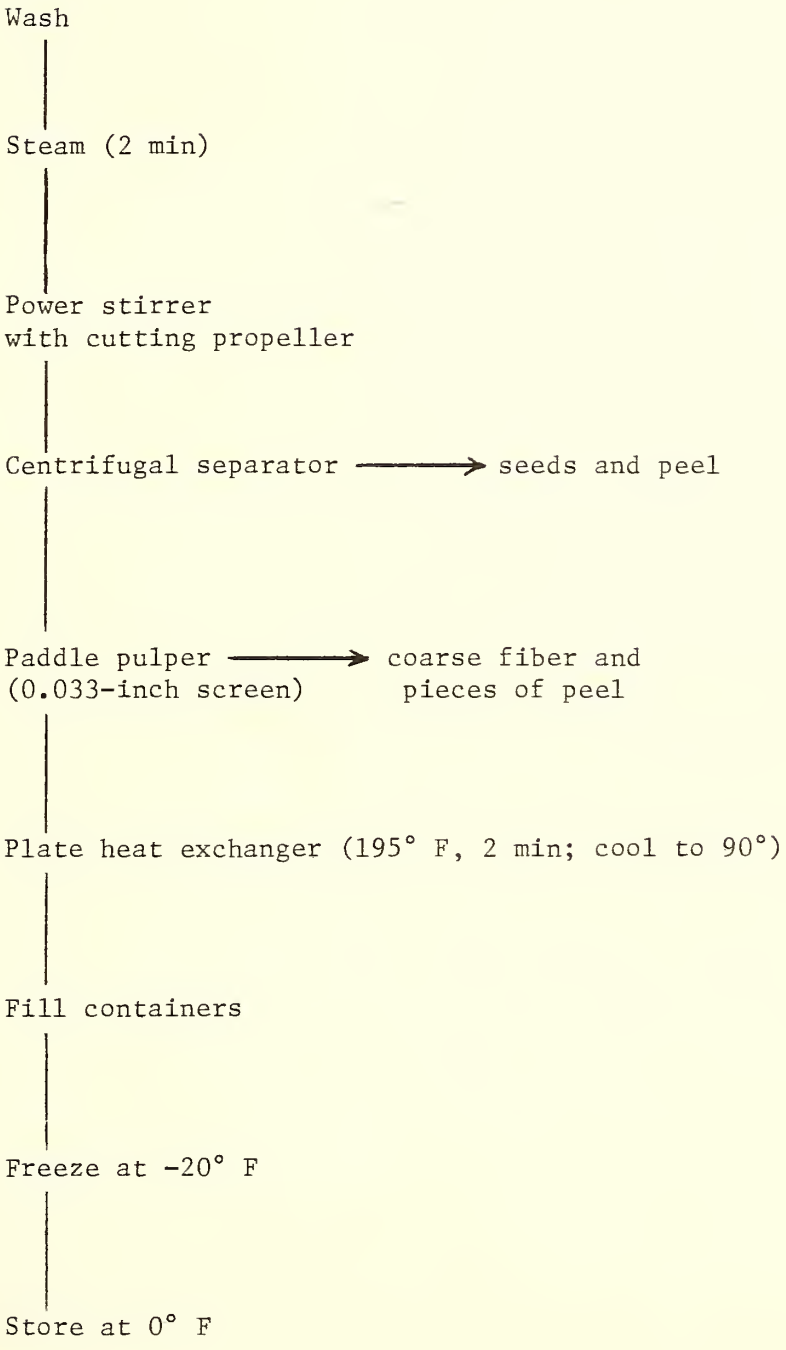
Forty grams of puree is extracted with 100 ml of 70-percent methanol in water. Five grams of Filter Cell (Johns-Manville Co.) is stirred into the

5/ National formulary quality.

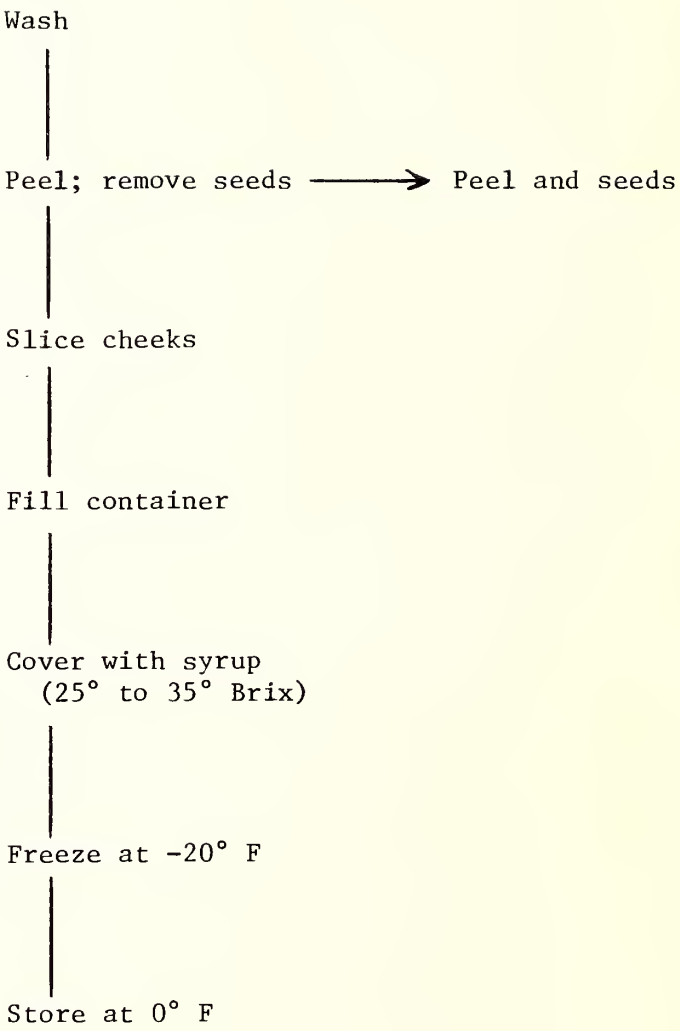
extraction mixture, which is then filtered in vacuum through a thin pad of Filter Cell on Whatman No. 2 filter paper. The filtrate is diluted to 200 ml with 70 percent methanol. The absorbance ($A = \log_{10}\frac{1}{T}$) at 400 nm is measured with a spectrophotometer.

Processing Flow Sheets

Frozen Puree



Frozen Slices



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